OPERATING AND INSTRUCTION MANUAL

MODEL PSC-419 S-2288

PHASE-SENSITIVE CONVERTER

north atlantic
INSTRUMENT DIVISION

OPERATING AND INSTRUCTION MANUAL

MODEL PSC-419 S-2288

PHASE-SENSITIVE CONVERTER

Revised 8/8/74

NORTH ATLANTIC INDUSTRIES, INC.
Hauppauge New York

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BRUNING 40-135 32372

NORTH ATLANTIC Industries, Inc.
60 plant avenue, hauppauge, n. y. 11787 516-582-6500

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CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

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SECTION I

GENERAL DESCRIPTION

INTRODUCTION

The North Atlantic Phase Sensitive Converter performs a precise conversion of an AC input signal into a high level DC output linearly proportional to the average value of the full wave rectified input. When used in the Phase Sensitive Modes, the output is proportional to the average value multiplied by the cosine (In-Phase) or sine (Quadrature) of the angle between the signal and reference inputs. Orthogonality with respect to the frequency is maintained over a bandwidth of 5% through the use of matched, low phase gradient circuits. High degeneration in all circuits results in excellent linearity characteristics. Matched, high rejection filters eliminate errors due to harmonics in the signal and reference inputs. An output voltage of 0 to ±10V DC will be obtained for any full scale AC input voltage within the available input ranges. Refer to Specifications, "Input Voltage Range".

The instrument may incorporate shielded reference and signal isolation transformers which provide a means for ground isolation or a means for differential summing. Where the internal reference isolation transformer is not included, an external reference isolation transformer must be used.

SPECIFICATIONS

The following are the complete performance specification for the PSC-419-S 2288.

SPECIFICATIONS

I. PERFORMANCE CAPABILITY

Full Scale Input Voltage Range:	10mv, 100mv, 1V, 10V, 100V, 1000V for full scale output voltage.
Maximum Input Voltage:	Maximum AC 300V RMS Maximum DC ± 200V DC
Full Scale Output Voltage:	0 to ± 10V DC.
Function Modes:	Total, Fundamental, In-Phase, and Quadrature.
Output Polarity:	In-Phase Mode: The DC output voltage shall be positive when the signal input voltage is in the first (signal input leading the reference input by 0° to 90°) or fourth (270° to 360°) quadrants. When the signal input is in the second (90° to 180°) or third (180° to 270°) quadrants, the output shall be of negative polarity. Quadrature Mode: The DC output voltage shall be positive when the signal input voltage is in the first quadrant (signal input leading reference input by 0° to 90°) or the second quadrant (signal input leading the reference input by 90° to 180°). When the signal input is in the third (180° to 270°) or fourth (270° to 360°) quadrants, the output voltage shall be of negative polarity.
Reference Input:	Voltage: 115V ± 10% at 400 cps ± 20 cps. Input Impedance: Minimum 70K at 400 cps with isolation transformer.

Signal Input Impedance:

Direct Mode: 1 Meg resistive shunted by 100uuf capacity.

Transformer Mode: Shielded isolation transformer with minimum input impedance of 400K at 400 cps.

Accuracy:

Total: (Reference frequency is 400 cps. At this frequency, output is within 0.1% of full scale.) **(25°C)**

Direct Mode: 350cps to **1KC ±0.1%**
1KC to 10KC ±0.5%

Transformer Mode:
350cps to 1KC ± 0.1%
1KC to 10KC ± 1.0%

Fund:
In-Phase: ± 0.1% of F.S.
Quadrature 380 to 420 cps

Quadrature Rejection (In-Phase Mode): At 25°C, the maximum null when the signal input leads the reference input by 90° shall be 0 ± 0.1% of F.S. at 400 cps plus an additional .005% gradient tolerance for each cycle of deviation from 380 to 420 cps. These values shall apply for any signal from zero to full scale.

In-Phase Rejection (Quadrature Mode): The maximum null when the signal input is in-phase with the reference shall be 0 ± 0.1% of F.S.

(continued)

at 400 cps plus an additional .005% gradient tolerance for each cycle of deviation from 380 to 420 cps. These values shall apply for any signal from zero to full scale.

Frequency Response:

The frequency response of the converter shall be as follows for a 400cps amplitude modulated input signal voltage where the carrier reverses phase at the and 2π radian points (Nodes) of the modulated waveform.

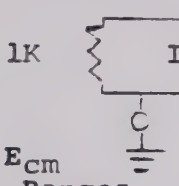
Amplitude: The output signal shall be flat within 0.1DB for a 400 cps signal modulated from 0 to 20 cps.

Phase Shift: The phase shift between the low frequency modulation waveform and the envelope of the demodulated output waveform shall vary linearly from 1° ± 1° at 1 cps to 5° ± 1° at 5 cps.

Harmonic Suppression:

Fundamental Mode:
2nd harmonic - 6DB nominal
3rd harmonic - 35DB minimum.
All higher order harmonics - 45DB minimum.

Phase Sensitive Modes:
2nd harmonic - at least 40DB
3rd harmonic - at least 45DB
All higher order harmonics - at least 45DB.

Common-Mode Rejection:	**Zero Source Impedance:** **All ranges - 400 cps .001%** **(Equivalent differential input).** **All ranges - 3Kc .1%** **(Equivalent differential input).**
1K Source Impedance:	 All Ranges - 400 cps .03% (Equivalent differential input). All Ranges - 3KC .3% (Equivalent differential input)
Output Impedance:	1.0 ohms
Maximum Output Current:	1.5ma
Settling Time:	0.1 second to be within 0.1% (full scale) of final value.
Overload Recovery:	After removal of 300V RMS signal from the input, the output signal shall return to ±.02V of its final steady-state value within 2.5sec.
DC Output Offset (Shorted Input):	In-Phase and Quad - DC output ± 10mv max. Total and Fund - DC output ±20mv max.

AC Output Noise:	At 10mv input signal on 10mv range, AC output shall be 6mv RMS, max.
Effect of Non-Synchronous Power Frequency:	There is no degradation of performance when the frequency of the power input voltage is not synchronized with the frequency of the signal and reference input voltages.
Over-Voltage Protection:	Voltages of up to 300V RMS can be applied directly to the input of the converter or any range without damage to the converter. Input Impedance specifications are not applicable during over-voltage condition.
Input-Power:	115V ± 10%, 50-420cps. Maximum current 0.2 amperes.
Programming:	6 ranges (10mv, 100mv, 1V, 10V, 100V, 1000V) 300V maximum on 1000V range. 4 functions (Total, Fund, In-Phase, Quadrature) Direct/Transformer Modes.
Programming Signal:	Programming will be with non-latching relays requiring an input of 28 ± 4 volts continuously. Power consumption is approximately 1-1/2 watts per relay.
Ground Circuits:	Internal signal ground shall be isolated from the case. For proper operation, internal signal ground must be connected to chassis ground externally.

Fusing:	.5 amp. Slo-Blo fusing shall be externally supplied for power input.
Temperature Coefficient of Scale Factor Specification:	± [Nominal tolerance in % at 25°C +.003% x Δ°C] of full scale from -40°C to +74°C. Where Δ°C = difference between operating temperature and 25°C.
Temperature Coefficient of Quadrature and In-Phase Rejection Specification:	± Nominal tolerance in % at 25°C + .004% x Δ°C from -40°C to +74°C. Where Δ°C = difference between operating temperature and 25°C.

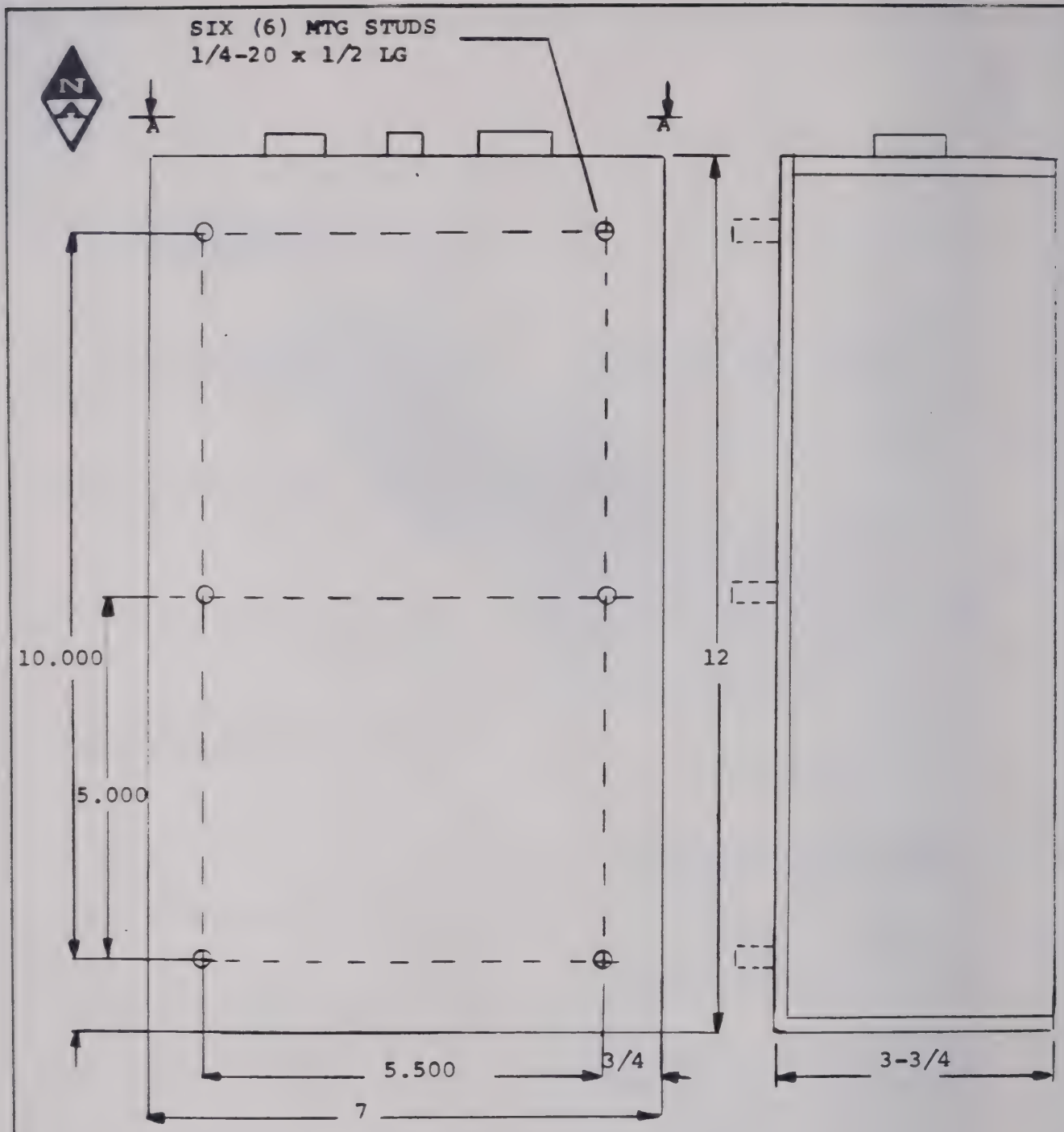
II. DESIGN AND CONSTRUCTION

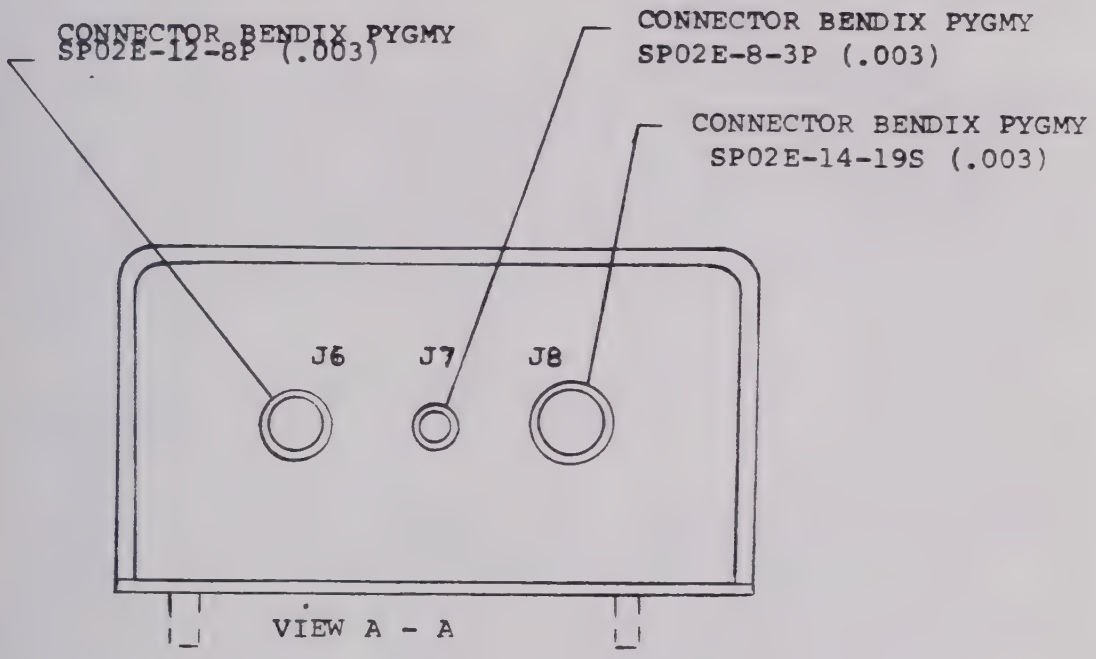
This unit shall be designed and constructed in accordance with MIL-T-21200, Class 3.

Temperature (Operating):	-40°C to 74°C (See Temperature Coefficient paragraphs above).
Temperature (Non-operating):	-62°C to 85°C.

III FINISH

Gray - Vinyl Clad Aluminum Covers and Clear Anodized Aluminum Extrusion Frame.


SIX (6) MTG STUDS
1/4-20 x 1/2 LG
A
A
10.000
5.000
12
5.500
3/4
7
3-3/4


CONNECTOR BENDIX PYGMY
SP02E-12-8P (.003)
CONNECTOR BENDIX PYGMY
SP02E-8-3P (.003)
CONNECTOR BENDIX PYGMY
SP02E-14-19S (.003)
J6
J7
J8
VIEW A - A

SECTION II

OPERATING INSTRUCTIONS

REMOVAL FROM PACKAGE

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obious damage. Should such be observed, refer to the Warranty Policy.

INITIAL CONNECTION

Apply power, 115V, 50-420Hz, to Pins A and B of connector J7. The components of the Converter will require a 15-minute warm up before stable operating conditions are reached.

CAUTION: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

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Apply input signal to Pins A and B of connector J6 with Pin B used as the low side. The AC reference input is applied to Pins E and F of connector J6 with Pin F used as the low side.

NOTE: The voltage at Pin E is in-phase with the voltage at Pin A. A positive DC output will appear across Pins C (High) and D (Low) of connector J6 for

Total, Fundamental, and In-Phase inputs. An input signal which is at an angle of 90° or 270° with respect to reference in the In-Phase Mode will produce 0 volts output.

GROUNDING

In order to prevent system ground loops, the chassis of this instrument has been isolated from the instrument circuit ground. It is necessary, however, for proper operation of the instrument that circuit and chassis ground be at the same potential - i.e., connected together. This is normally done external to the instrument. *The instrument circuit ground is brought out on Pin H of J6 (see schematic diagram, Figure 3.2), which is the low side of the input. This point can be used to connect instrument circuit ground to chassis ground. This must be done at only one point.

The ground connections in the system external to the Phase Sensitive Converter must, therefore, be reviewed to avoid such ground loops.

In addition, the low side of the power source should be tied to Pin B of J7. This will reduce the effect of stray currents.

*NOTE: Do not tie chassis ground to signal ground on Pin D of J6 (low side of output).

PROGRAMMING

Function and Range - The desired operating conditions may be selected by applying a 0.0V DC to the appropriate pins of connector J8 (see programming section) and Pin F at +28V DC (±4V)

Function Selection - The Function Program is used to select the desired mode of operation. One of four available modes

may be selected:

Total Mode - The DC output signal is proportional to the entire AC input signal (RMS).

Fundamental Mode - The DC output signal is proportional to the RMS magnitude of the fundamental component of the input signal.

In-Phase Mode - The DC output signal is proportional to that component of the input signal which is in-phase with the reference signal.

Quadrature Mode - the DC output signal is proportional to that component of the input signal which is at a phase angle of 90° with respect to the reference signal.

Range Selection - The Range Program is used to select one of six (.01V, .1V, 1V, 10V, 100V, 1000V) available input ranges. (Note 300V maximum on 1000V range)

Input Selection - The input program is used to select either of two available input connections. A direct (capacitor coupled) connection or a transformer isolated input connection may be chosen as desired.

OPERATION

This instrument will operate within the specified accuracy into any load in excess of 5100Ω.

Phase Trim - Because of source impedance effects, differences of frequency, etc., some small phase errors may be present between the Signal and Reference Channels. In order to trim these errors, the following procedure should be followed.

Program range to the most sensitive range and function to the Quadrature Mode. Apply an in-phase signal equal to the most sensitive full scale value to the input terminals. The output should be 0 ± 10mv. If not, the output may be zeroed by adjusting R1116 which is found beneath the Phase Trim button on the top of the instrument.

CONNECTOR INFORMATION FOR PSC-419-S2288

8 Pin Connector, J6

A - HI Sig. Input
B - LO Sig. Input
C - HI DC Output
D - LO DC Output
E - HI Ref. Input
F - LO Ref. Input
*H - INTERNAL SIGNAL GROUND

Pin F is the return line for all relays connected to +28V DC.
*Pin H must be connected to the source ground in the transformer isolated input mode.

3 Pin Connector, J7

A - HI 115V
B - LO 115V Power
C - Chassis Ground

19 Pin Connector, J8 (Programming)

To program to the desired range or function, apply a ground return to the appropriate pins as indicated. (Note that a positive polarity power supply +28V DC (±4V DC) must be used for Pin F.

Range	Energize
.01V	DKV
.1V	D
1V	DK
10V	KV
100V	
1000V	K

Function	
Total	P
Fundamental	AP
In-Phase	AM
Quadrature	A

Input	
Direct	
Transformer	U

SECTION III

THEORY OF OPERATION

GENERAL

The block diagram and schematic of Figures 3.1 and 3.2 serve to illustrate the principles of operation of the Phase Sensitive Converter.

The Phase Sensitive Converter, as stated previously, has the capability of providing DC outputs proportional to the AC inputs in four different function modes, as desired. The Phase Sensitive Converter has two independent channels. The Total and Fundamental Modes of operation make use of the Signal Channel only, much in the same manner as a conventional voltmeter. The difference between the two modes is the insertion of a harmonic filter in the Fundamental Mode to limit the frequency response to the design frequency. The Reference Channel is disabled during these modes of operation. For phase sensitive operation (In-Phase and Quadrature Modes), the Reference Channel is activated. The reference signal is amplified and phase shifted by the reference circuitry. This signal serves to gate the demodulator. The phase relationship of this gating voltage to the signal being measured will determine the magnitude and the polarity of the DC output voltage. The output voltage will change as a cosine function of the phase angle from 0° through 360°.

The following paragraphs are a detailed description of the above-mentioned channels and their various components.

PLUG-IN MODULES

The amplifiers used in the Phase Sensitive Converter are of silicon solid-state design. These are contained within the plug-in modules along with relays and other circuit components. All designs are based on the use of components well below maximum manufacturers' ratings to insure long life and trouble-free operation. These modules are factory sealed and in the event of failure should be replaced as a unit. The individual modules are described as follows:

Range Attenuator Assembly

The Signal Channel of the PSC-419 always operates with a basic full scale sensitivity of 10mv. This requires attenuators for reducing higher level voltages to this range. The input attenuator actually consists of 3 separate voltage divider networks. They provide attenuations of 1000:1, 100:1 and 10:1. The dix full scale ranges are selected by programming each of the attenuators individually or in combination. When properly adjusted, they provide the necessary attenuation over the frequency band required for Total Mode operation and essentially zero phase shift for Phase Sensitive operation.

The 1000:1 attenuator is iolsated from the other two attenuators by a unity gain, high impedance input, isolation amplifier which is included inside the module.

Signal Input Assembly

This assembly contains the Signal Pre-Amplifier which provides a stable gain of 70 which is necessary for the 10mv sensitivity of the instrument. Large amounts of negative feedback are used so that its gain is controlled soley by stable precision resistors. Its design is such that it provides a wide band frequency response with minimal phase shift and low noise. Also contained within this module are the source and load resistors for the signal filter L1, a resistive network which simulates the attenuation of the filter when the instrument is programmed into the Total Mode, and K1502 which switches between the two circuits. Relay K1501 switches components into the circuit in the Transformer Input Mode. It is the function of these components to compensate for the Signal Isolation Transformer frequency characteristics.

Signal Output Assembly

The Signal Output Assembly contains a unity gain, isolation amplifier and a signal amplifier. It is the function of the isolation amplifier to present a high impedance load to the signal input amplifier and to present a low impedance source to the output signal amplifier.

The output signal amplifier has a very high gain bandwidth product resulting in a phase shiftless power gain. The power gain is required to drive the demodulator circuit which is contained in the Gated Signal Converter.

Reference Input Assembly

This assembly contains the phase shift network, the phase trim network, and a square wave generator circuit as well as two isolation amplifiers. It is the function of the phase shift network to provide an accurate 90° phase shifted reference signal in the Quadrature Mode. The 0° network provides a like amplitude signal at an angle of 0° in the In-Phase Mode. Because of the phase shift network's sensitivity to resistive and capacitive loads, an isolation amplifier is inserted at this point. This isolation amplifier not only provides the high impedance, low capacity load to the phase shift network but provides a low impedance source to the phase trim network.

The phase trim network provides the capability of aligning the overall phase shift in the Reference Channel to coincide with the Signal Channel. This circuit also being sensitive to loads requires that it be isolated from the succeeding circuitry. The second isolation amplifier is included for this purpose. At this point in the Reference Channel, the reference filter L2, which is located outside of the module, is connected. The filtered reference signal is now fed into the Square Wave Generator. It is the purpose of the Square Wave Generator to amplify and clip the reference signal so that the zero crossing of the reference signal is accurately preserved.

Also contained within the module are relays K1101 and K1102. It is the function of K1101 to select the 0° or 90° output from the phase shift network. K1102 disables the Reference Channel in the Total and Fundamental Modes by shorting the output of this module to ground.

The module described above is designed to operate with a relatively fixed reference voltage input. As an option, a variation of this module is available which will operate with a 10:1 variable

reference input voltage. Its basic operation is the same as that described above with the exception of added circuitry which allows the input voltage to be variable.

Gated Signal Converter

This module contains the circuitry which performs the ultimate operation of converting the AC input signal to a DC output. In the Total and Fund Modes, the demodulator is self-gated by the AC voltage from the Signal Output Amplifier. The pulsating DC output of the demodulator is differentially summed in the DC differential amplifier. The unipolar output of the differential amplifier is then fed out of the module to the output filter L3 where the AC component is filtered out. This filtered signal is then fed back into the module to a DC amplifier which provides the extremely low output impedance and power gain to the output terminals of the converter.

In the Phase Sensitive Modes, the square wave output of the reference input module is amplified by the square wave amplifier and coupled to the Phase Sensitive Demdulator. It is the purpose of the reference signal to synchronously gate the Phase Sensitive Demodulator so as to accurately convert the AC signal to a DC signal as a function of phase shift.

The Phase Sensitive Demodulator operation can be likened to that of a set of commutating switches which alternately connect the output of the Signal Channel to the differential amplifier. A portion of this demodulated signal which appears across R1390 is fed back to the signal output module. This feedback is used to eliminate the effects of component non-linearity.

In the Phase Sensitive Modes when the reference and signal voltages are in-phase, the DC output signal will be maximum. When these voltages are 90° apart, the result will be a null and the DC output will be zero.

Power Supply

The power supply of the PSC 419 is designed to provide several different DC voltages. Each of these DC voltages is well filtered and with the exception of the +60V is zener regulated.

Filters

Signal and reference filters, L1 and L2, NAI #202626-1, are low pass filters designed to cut off frequencies above the operating frequency. Their use in the Signal and Reference Channels provides sufficient rejection of harmonics and noise consistent with the overall instrument specifications. In addition, these filters contain compensation for amplitude variation with temperature.

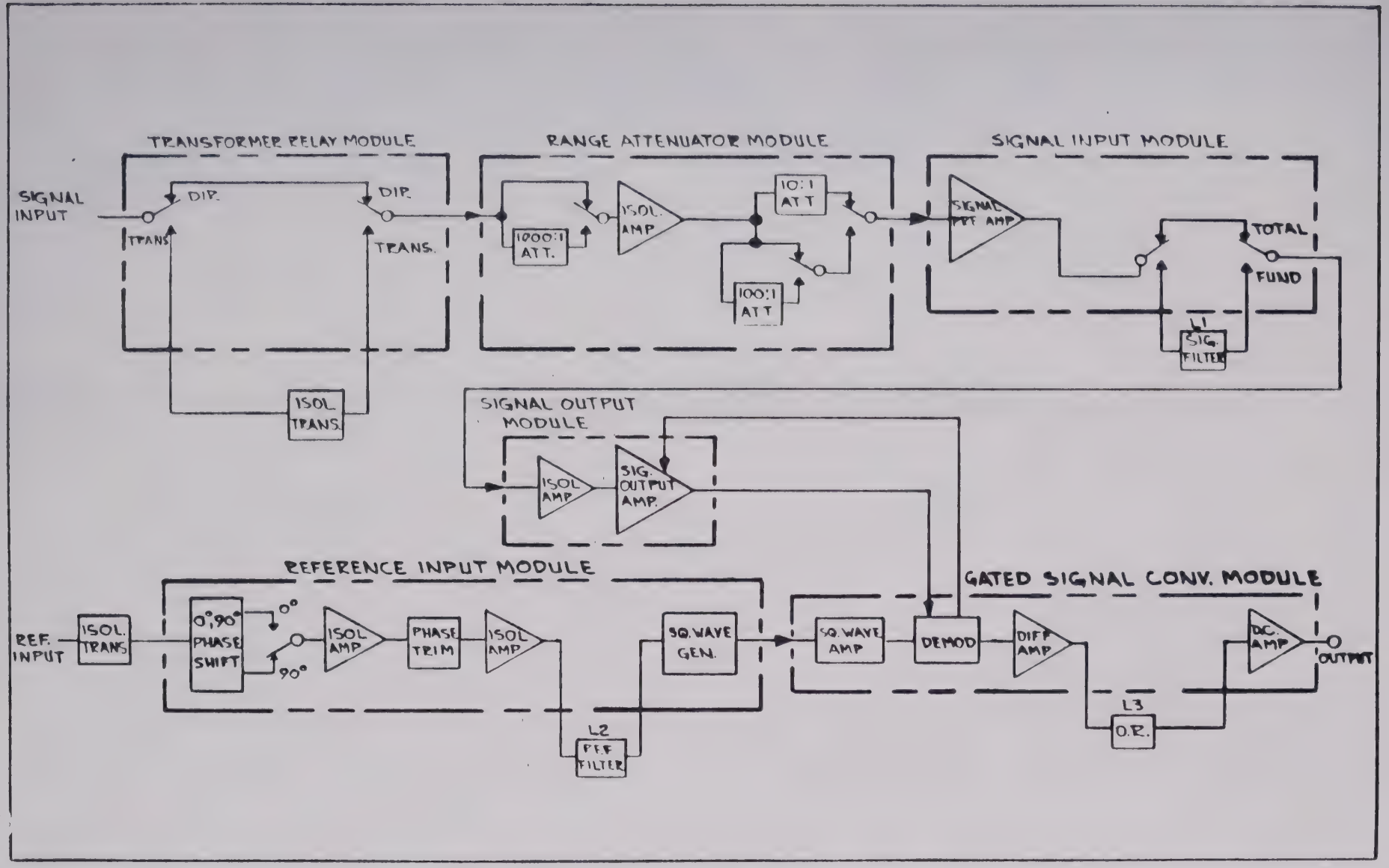
Output Filter L3, NAI #801030 is an exceedingly flat, low pass filter with a cut off at 400~. This filter is designed to result in an optimum between maximum filtering of ripple and minimum settling time. As an option, an alternate output filter is available (NAI # 801429) which is intended for use in instruments where the frequency response is extended down to 60~.

Isolation Transformers

The isolation transformers may be included as a means for isolating ground circuits from the signal and/or reference inputs to the Phase Sensitive Converter. This allows the instrument to be used for making isolated or differential measurements and removes the possibility of ground loops. Both transformers are specially designed and are well shielded for optimum performance for their specific functions.

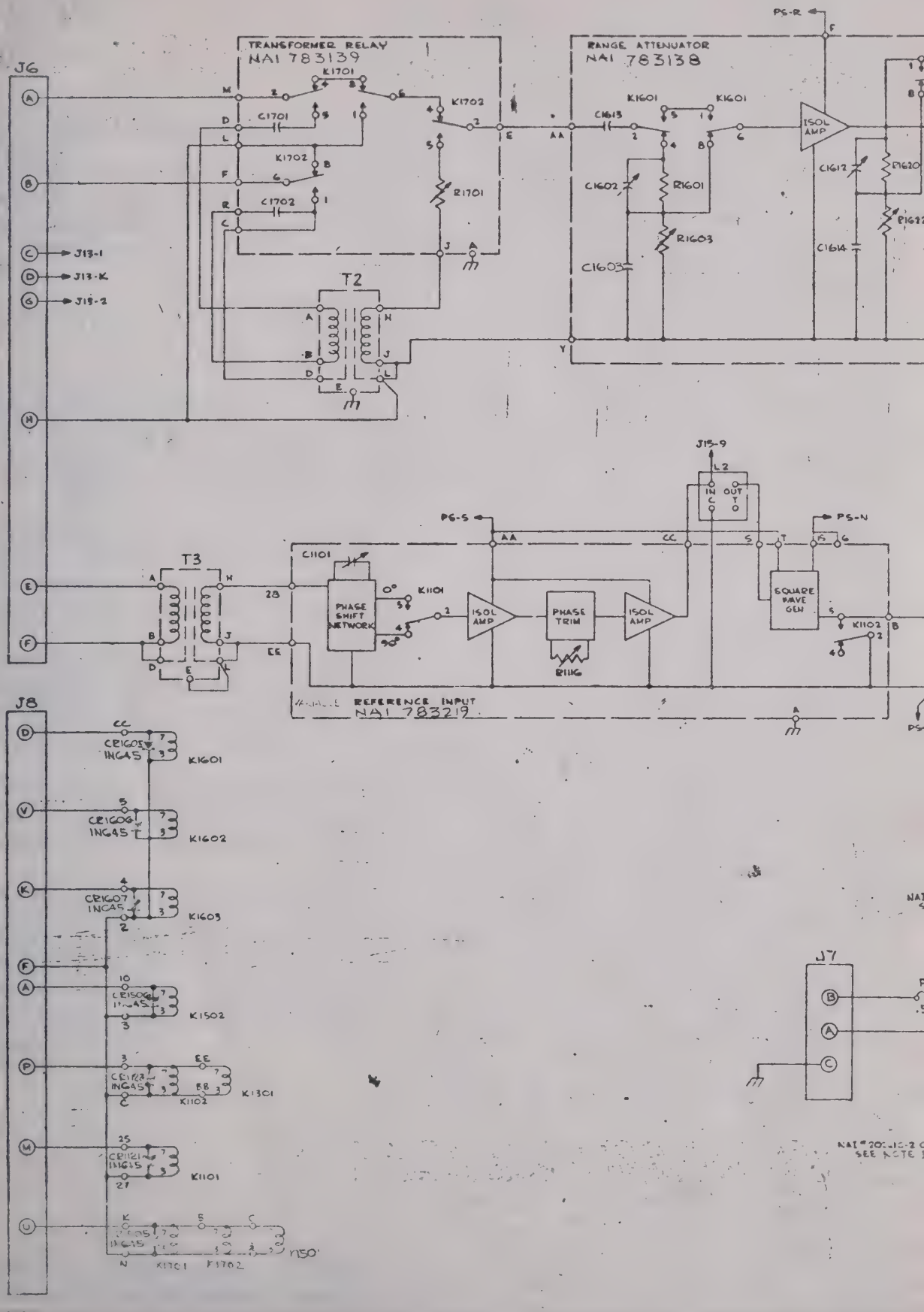
The Transformer Relay Assembly contains the relays required for switching the Signal Isolation Transformer T2 in and out of the circuit as desired. It also includes blocking capacitors which allow a signal containing a DC component to be applied to the input while in the Transformer Mode.

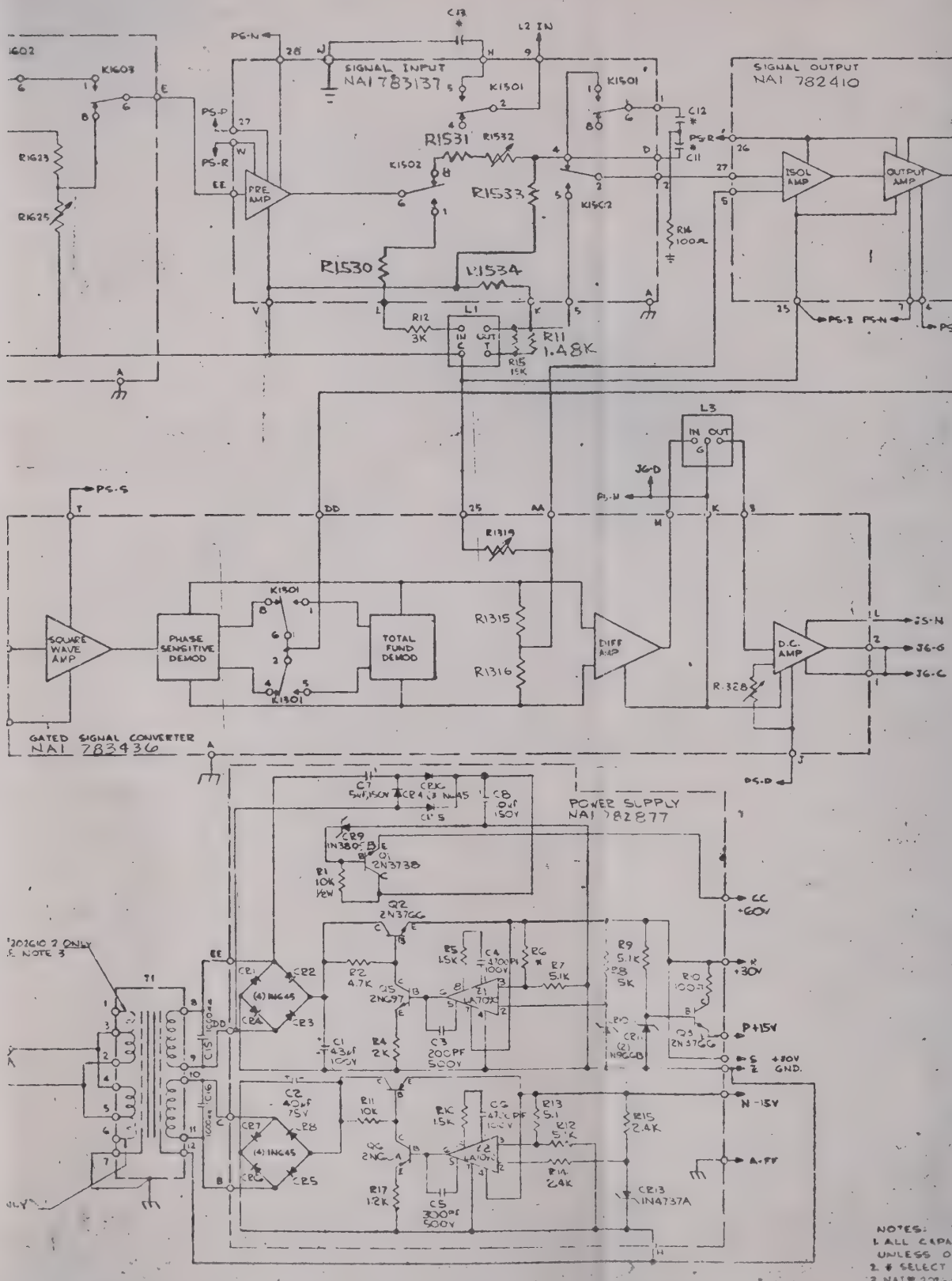
The variable resistor R1701 adjusts the gain of the transformer so that it is equivalent to the direct input mode gain.



BLOCK DIAGRAM
Figure 3.1

DSG-410-82288


REV A
REV B 11/13/74
J6
TRANSFORMER RELAY
NAI 783139
K1701
K1702
C1701
C1702
R1701
T2
T3
RANGE ATTENUATOR
NAI 783138
K1601
C1613
C1602
R1601
R1603
C1603
C1612
R1620
C1614
ISOL AMP
PS-R
J13-1
J13-K
J13-2
J15-9
L2
PG-S
PS-N
C1101
PHASE SHIFT NETWORK
K1101
PHASE TRIM
R1116
SQUARE WAVE GEN
K1102
REFERENCE INPUT
NAI 783219
J8
CR1605 IN645
CR1606 IN645
CR1607 IN645
CR1502 IN645
CR1123 IN645
CR1121 IN645
K1602
K1603
K1502
K1301
J7


SIGNAL INPUT
NAI 783137
SIGNAL OUTPUT
NAI 782410
PRE AMP
ISOL AMP
OUTPUT AMP
R1530
R1531
R1532
R1533
R1534
R1535
R1536
R1537
R1538
R1539
R1315
R1316
R1328
R12 3K
R11 1.48K
R15 15K
RM 100Ω
L1
L2 IN
L3
PS-N
PS-P
PS-R
PS-S
PS-D
PS-Z
PS-CC
JG-D
JG-G
JG-C
JS-N
SQUARE WAVE AMP
PHASE SENSITIVE DEMOD
TOTAL FUND DEMOD
DIFF AMP
D.C. AMP
GATED SIGNAL CONVERTER
NAI 783436
POWER SUPPLY
NAI 782877
+60V
+30V
+15V
+8.0V
GND.
-15V
-PP
NOTES:
1. ALL CAPACITORS ARE IN μfd UNLESS OTHERWISE SPECIFIED.
2. # SELECT IN TEST
3. NAI® 202610-1 IS SUPPLIED AS A STANDARD TRANSFORMER AND DOES NOT INCLUDE WINDINGS 1 & 6. NAI® 202610 2 IS SUPPLIED ON SPECIAL ORDER
4-LATCHING RELAY CONNECTIONS ARE SHOWN AS DOTTED LINES.
5-ALL RELAYS ARE SHOWN IN DE-ENERGIZED POSITION.
SCHEMATIC
DSC 810 (521A)

Errors Caused by Harmonics in Various Types of Detectors

The manner in which harmonic distortion affects AC to DC conversion accuracy of a pure sinusoidal fundamental signal depends on the detector used. There are three general methods of performing AC to DC detection.

1. Averaging detector
2. "True RMS" converter
3. Peak detector

The first (averaging) is used commonly in vacuum tube voltmeter circuitry. A typical averaging detector circuit can result in the range of errors listed in Table I as a result of second and third harmonic content in theAC signal being measured.

Converting AC to DC in a true RMS manner reduces errors due to harmonics in those cases where the harmonic amplitude is low compared to fundamental, but not where the harmonic amplitude is high (compared to fundamental) as shown in Table 2.

A peak detector would result in errors which may be as great as the percentage of harmonic content in the signal being measured. This applies for all orders of harmonics and depends mainly on the phase relationships between the fundamental and each of the harmonics.

The above three basic techniques all convert an AC waveform to a DC value by straightforward rectification of conversion, independent of the phase of the measured signal.

In the phase sensitive detector, even order harmonics have no effect on the results. Error due to odd order harmonics is the percent distortion divided by the order of the harmonic. For example, 9% third harmonics would result in an error of 9 divided by 3, or 3%. Table 3 shows the errors that may be expected from the phase sensitive detector for the same conditions listed in Tables 1 and 2.

Table 1 - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

Table 2 - Theoretical Errors Due to Harmonics in True RMS Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	+0.5%
2nd	20%	+2%
2nd	50%	+12%
3rd	10%	+0.5%
3rd	20%	+2%
3rd	50%	+12%

Table 3 - Theoretical Phase-Sensitive Average-Detector Errors Due to Harmonics

Harmonic Order	Harmonic Content	Theoretical Error (No Filters)
2nd	10%	None
2nd	20%	None
2nd	50%	None
3rd	10%	-3.3% to +3.3%
3rd	20%	-6.7% to +6.7%
3rd	50%	-16.7% to +16.7%

In order to determine the effects of harmonics on the ring bridge demodulator circuit, consider the introduction of second harmonic which is in the same phase as the reference (Figure 3.3). The current through the meter has an average value equal to 0. Figure 3.4 shows that a second harmonic signal which is out of harmonic phase also has no effect. Once again, the average value is zero. Thus, a phase sensitive detector similar to a ring bridge is unaffected by second harmonic distortion regardless of the phase of the harmonic. The same analysis can be carried forth for all even-order harmonics.

Let us now consider the introduction of third harmonic. Where the third harmonic is in harmonic phase with the reference (Figure 3.5), there are four positive half cycles flowing through the meter and two negative half cycles. Therefore, the current flowing through the meter circuit is 1/3 the value of the same amplitude of fundamental frequency applied as a signal. A third harmonic out of harmonic phase would result in the waveform shown in Figure 3.6. The resultant DC current is again 0. Therefore, the effects of odd-order harmonic on a phase sensitive detector can be anything from zero (where the harmonic is out of harmonic phase) up to a reading equal to the ratio of the harmonic amplitude to the fundamental reduced by a factor of the order of the harmonic (where the harmonic is in harmonic phase with the fundamental).

A general expression of the signal produced by any odd harmonic is thus:

$$I_m = K \frac{E_h}{nE_t} \cos \theta_h$$

Where I_m = DC output current; K = proportionality constant; E_h = RMS value of harmonic; E_t = RMS value of fundamental; n = order of harmonic; θ_h = harmonic phase (defined in degrees of harmonic as related to the zero crossing of the fundamental). This potential "Harmonic error" is eliminated by the filters in both reference and signal channels of the phase sensitive converter.

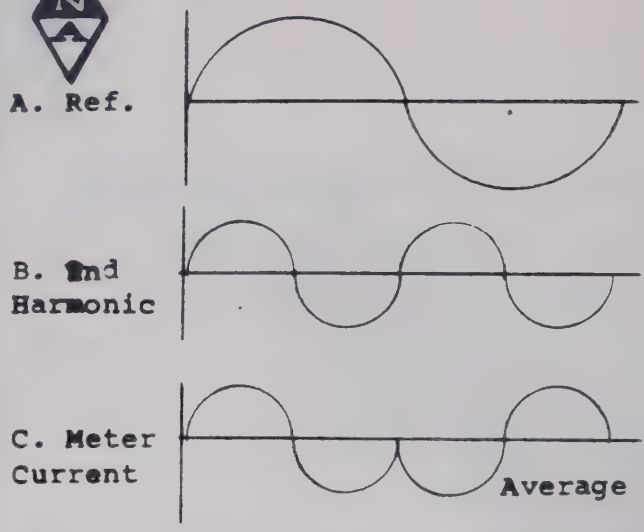


Figure 3.3 SECOND HARMONIC in phase with reference has no effect on reference controlled bridge demodulator.

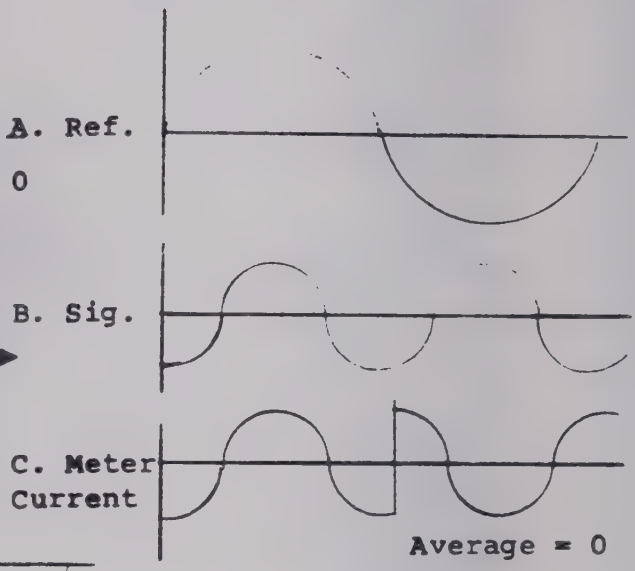


Figure 3.4 SECOND HARMONIC has no effect when out of phase with reference.

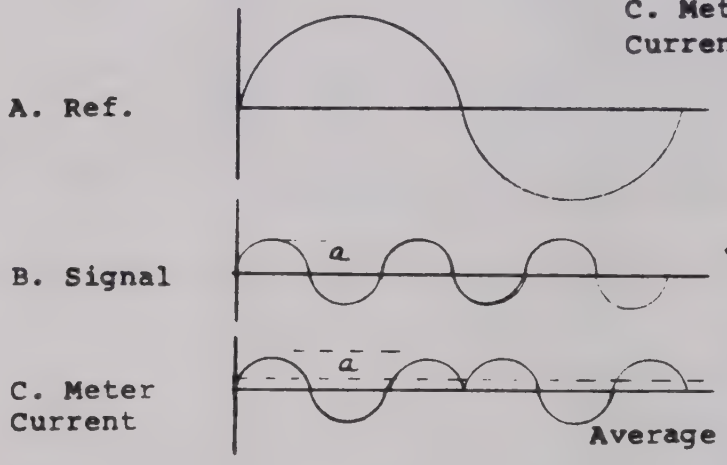


Figure 3.5 THIRD HARMONIC (in phase) does affect the output.

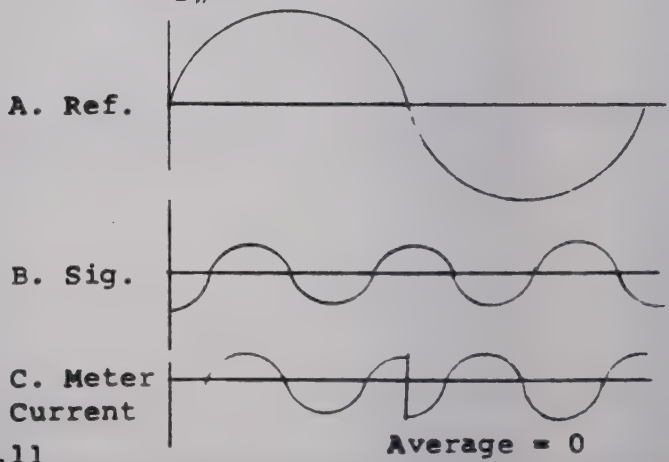


Figure 3.6 THIRD HARMONIC (out of phase) does not affect the output.

SECTION IV

MAINTENANCE

The following section contains instructions for the maintenance of the Phase Sensitive Converter.

COVER REMOVAL

To remove cover, remove 10 screws from the sides and top of the U-shaped cover. In the event that the instrument must be trouble shot, it will be necessary to remove the bottom cover which is held in place by 6 screws.

AMPLIFIER AND COMPONENT REPLACEMENT

Remove two screws on either side of the amplifier to be removed. The amplifier may then be unplugged from its socket and replaced. Upon replacement, part numbers must be checked to guarantee proper location and hold-down screws must be replaced at either end of the module. The Isolation Transformers and Transformer Relay Assembly are also plug-in modules. In order to remove them, two screws must be removed from the underside of the chassis.

CAUTION: The Reference Isolation Transformer is held in place with insulated screws. When re-installing this transformer, these same insulated screws must be used.

RELAYS

All relays are plug-in relays. To replace these relays, it is first necessary to remove the module from its socket. The two screws must then be removed from the relay hold-down bracket. The relay may then be removed and replaced. Upon replacing the relay bracket, the case of the relay should be checked to see that it is connected to case ground of the modules (Pin A of the module connector).

REPLACEMENT PARTS LIST

Designation	Description	NAI Part No.
	Power Supply Assembly	782877
	Fixed Reference Input Assembly	782420
	Gated Signal Converter Assembly	783436
	Signal Output Assembly	782410
	Signal Input Assembly	783137
	Range Attenuator Assembly	783138
	Transformer Relay Assembly	783139
	Signal Isolation Transformer Assembly	782460
	Reference Isolation Transformer Assembly	782414
T1	Transformer, Power	202610-1
L1,L2	Filter	202626-1
L3	Filter	801030
J10,J11,J13-J16	Connector, PC, 56 contact	802947
J17	Connector, PC, 15 contact	802380
J21, J22	Connector, PC, 10 contact	803322

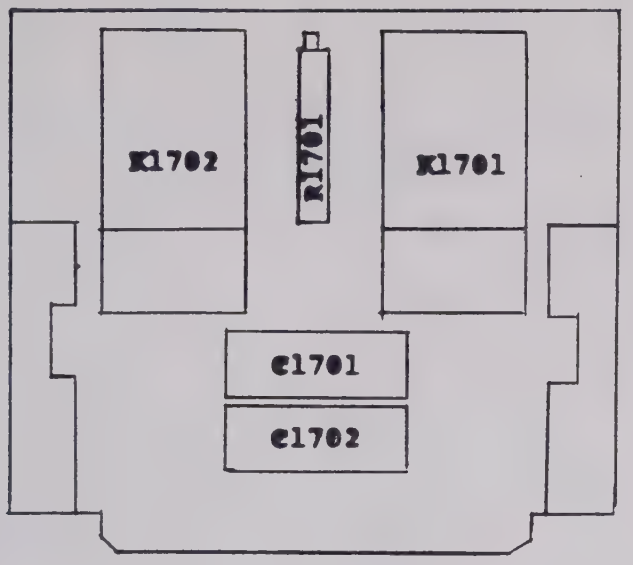
Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

REPLACEMENT PARTS LIST

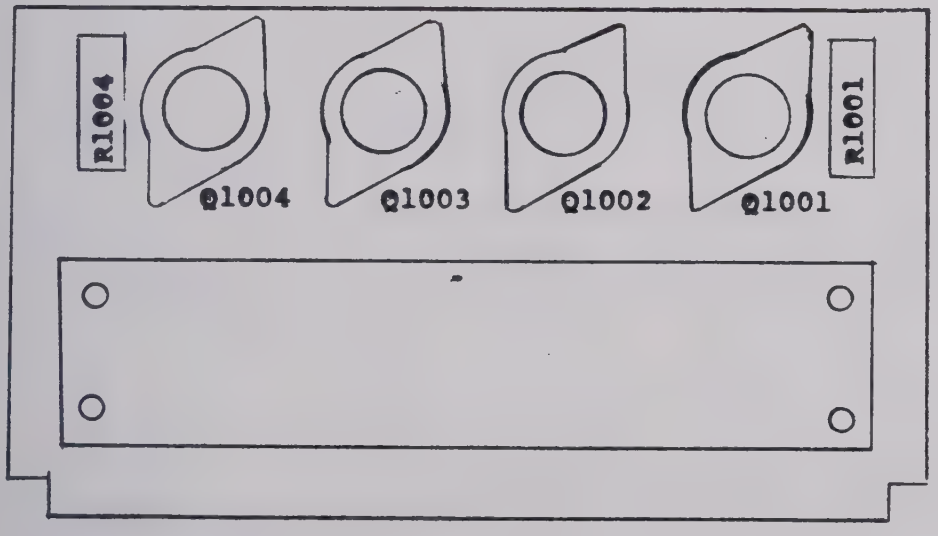
R11,R12	Resistor, Matched Set	203034-*
R13	Resistor, Fixed, DC, 15K, 1%, 1/2W	800066
R14	Resistor, Fixed, Comp., 100Ω, 10%, 1/4W	801412
K1101,K1102 K1301,K1501, K1502,K1601, K1602,K1603, K1701,K1702	Relay, 28V DC, Non-Latching	201880

*value to be determined at test

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.



TRANSFORMER RELAY ASSEMBLY



POWER SUPPLY ASSEMBLY

FIGURE 4.1

RELAY LOCATIONS

PSC-419-S2288

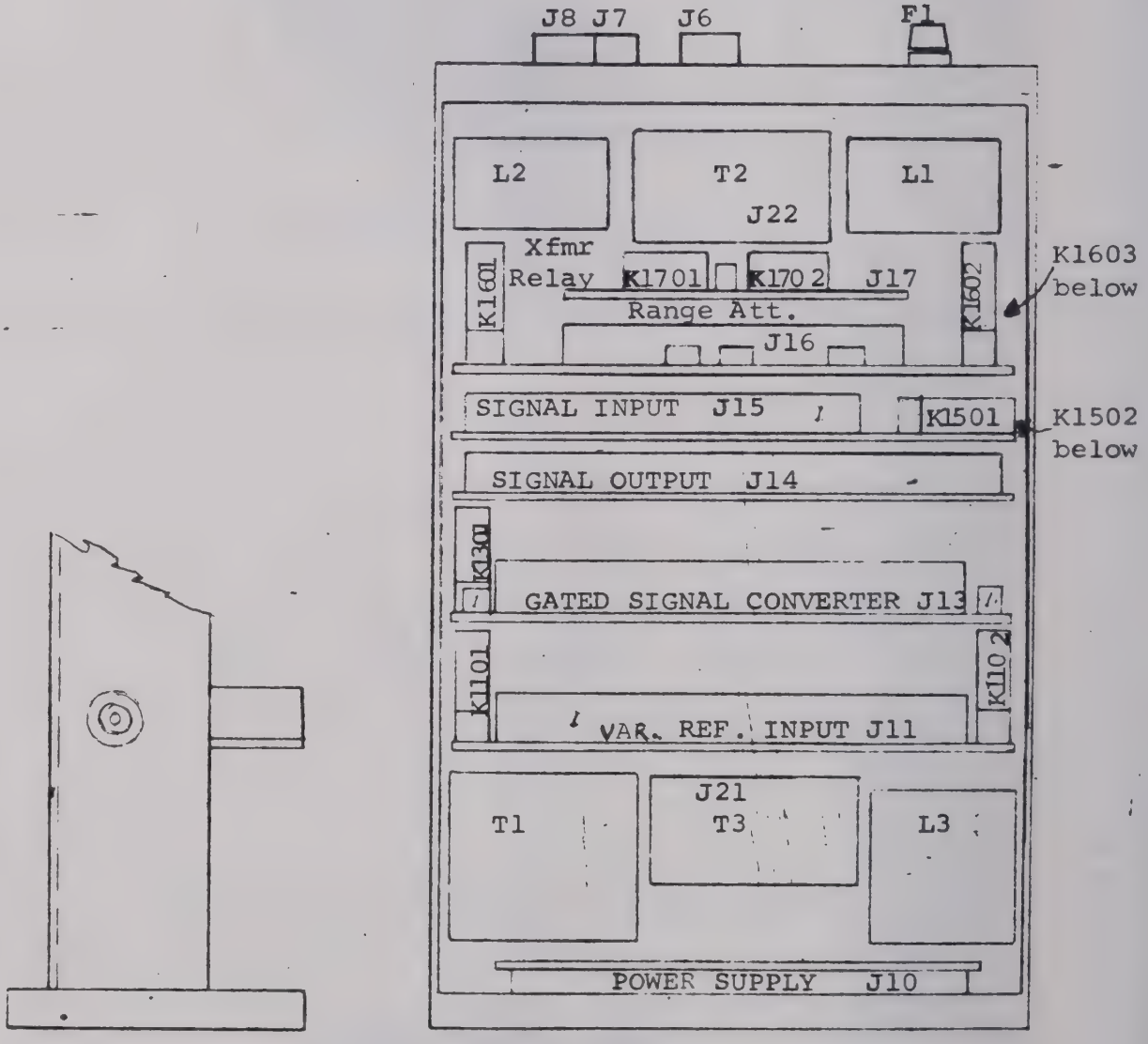


FIGURE 4.2

CALIBRATION ADJUSTMENT LOCATIONS

PSC-419- S2288

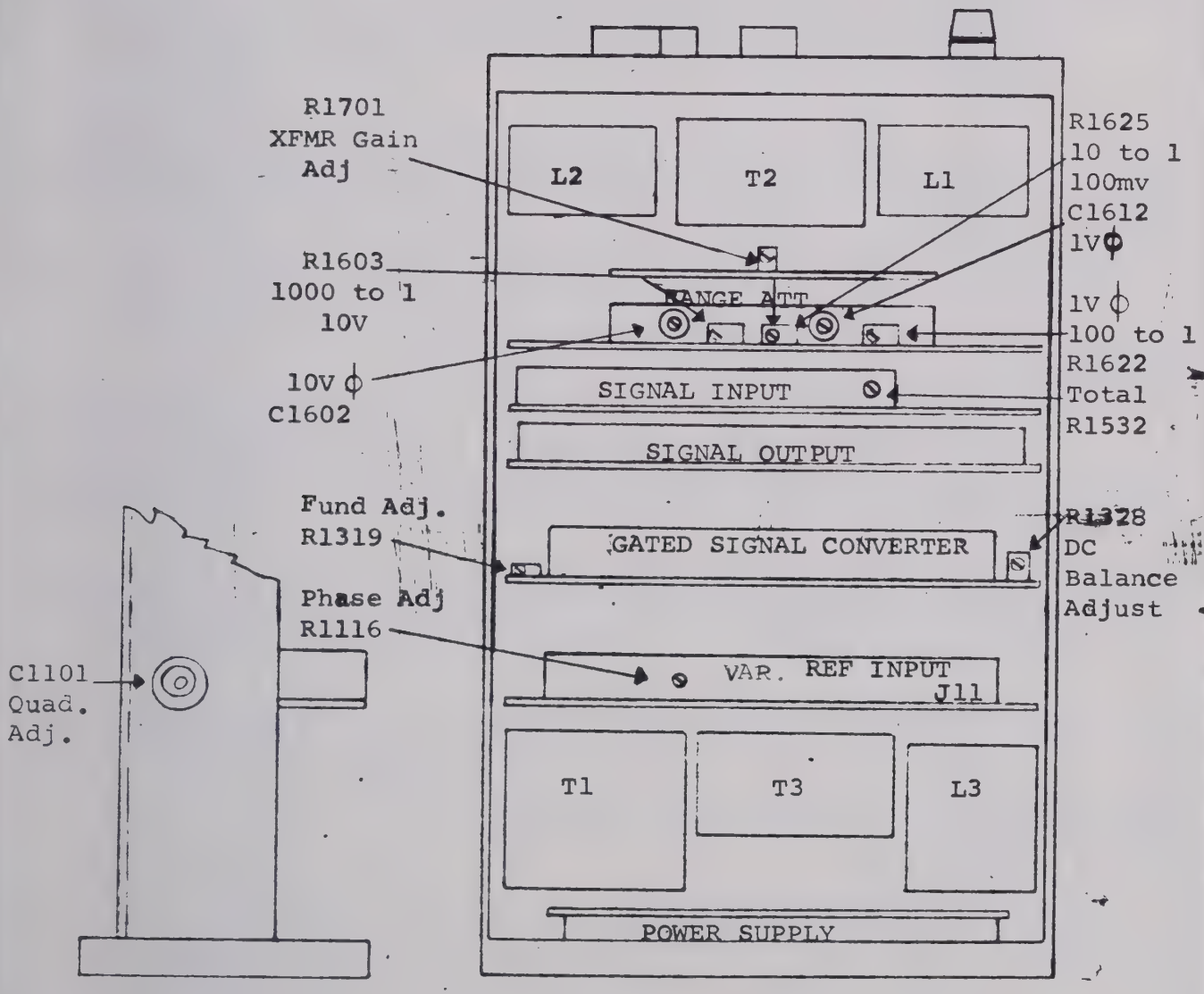


FIGURE 4.3

TROUBLE SHOOTING PROCEDURE

A. Malfunction of the PSC-419-S2288 would first be evidenced by improper output readings in the system. The primary power input, signal and reference inputs, and programming voltage should be verified prior to proceeding to trouble shoot the Phase Sensitive Converter since erroneous readings may be the result of a malfunction in the associated system equipment.

B. Having determined the erroneous reading are due to the Phase Sensitive Converter, the first trouble-shooting technique should be to replace any plug-in module, which may be suspected as the cause of the trouble (refer to the Theory of Operation, Section III). If the replacement of plug-in modules does not remove the trouble, it will then be necessary to investigate the individual components of the Phase Sensitive Converter.

C. There are certain components that, if defective, will render the instrument inoperative in all Ranges and Function Modes. The condition of these components should be checked if the unit is completely inoperative. These components are the Output Filter L3 and the Power Transformer T1.

D. The trouble-shooting chart will aid in isolating a malfunction in the instrument. An AC signal source and a 28V DC source will be required (see Section V for equipment required).

TROUBLESHOOTING CHART

TROUBLE	PROBABLE CAUSE	REMEDY
No reading or improper reading on Direct Mode input for all ranges and modes	Range Attenuator Ass'y Signal Input Ass'y Signal Output Ass'y Gated Signal Conv.	Check each module by plugging in a replacement.
	Filter L3, Relays K1701, K1702, K1501, K1502, K1301,	Check and replace defective components
Direct Mode:		
Improper reading on 0 - 100mv range only	Relays K1602, K1603	Checking winding, pins 3-7. Check between contacts. If defective, replace relay.
	Range Attenuator Ass'y	Check by plugging in replacement module.
Improper reading on 0-1V range only	Relays K1602, K1603	Check relays as above. Replace if defective.
	Range Attenuator Ass'y	Check by plugging in replacements module.
Improper reading on 0-10V range only	Relays K1601, K1602, K1603	Check relays as above.
	Range Attenuator Ass'y	Check by plugging in replacement module.

TROUBLE	PROBABLE CAUSE	REMEDY
Improper reading on 0-100V range only	Relays K1601, K1602, K1603	Check relays as above. Replace if defective.
Improper reading on 0-1000V range only	Relays K1601, K1602, K1603	Check relays as above. Replace if defective.
Direct Input, Total Mode		
Improper output, only in this mode	Signal Input Ass'y	Check and replace defective components
	Relay K1502	Check relay as above. Replace if defective
Direct Input, Fund Mode		
Improper output, only in this mode	Relay K1602	Check relay as above.
	Filter L1	Check Filter L1 and replace if defective.
Transformer Mode Input		
Improper reading, all ranges and modes. Proper reading, direct input	Relays K1701, K1702 Signal Input XFMR T1, Capacitors C1701, C1702, Resistor R1701	Check and replac defective components
Transformer Mode Input, Phase Sensitive Mode		
Improper reading on all ranges. Proper reading other modes, transformer input.	Relay K1501, Capacitor C13	Check relay as above. Check and replace defective components.

The PSC-419 contains a number of plug-in, sealed components and assemblies. If a malfunction is isolated to a plug-in relay, or one of the sealed, transistorized modules or components, the relay module or component must be replaced. No repair of the components is possible. The exposed circuit components on the assemblies and chassis can be replaced. Care must be taken to replace any of these components with those specified in the replacement parts list.

SECTION V

TEST AND CALIBRATION PROCEDURE

PERFORMANCE EVALUATION TEST PROCEDURE

I. Introduction

The data recorded as a result of following this procedure may be used for evaluation test on new units or as a routine calibration record, as required, by all customers. It should be followed if maintenance requires that components be replaced. In the latter case, the results obtained will determine the extent to which an instrument must be recalibrated and realigned.

II. Equipment Required

(a) Test Panel, North Atlantic #782266
(b) Precision DC Readout (Fluke Model 883A or equal)
(c) Precision AC Source:
    Oscillator (Krohn-hite Model 446R or equal)
    Amplifier (Krohn-hite Model DCA - 10R or equal)
(d) 28V DC ± 4V Power Supply (DB Model 21101B or equal)
(e) AC Monitor (Krohn-hite Model AC-601R or equal).
(f) Ratio Box, North Atlantic RB-503C or equal - 3 required
(g) Ratio Box, North Atlantic RB-504 or equal - 1 required
(h) Step-up Transformer 115:300, North Atlantic #782257 or equal.
(i) DC-VTVM (Hewlett-Packard 412A or equal).

NOTE: Prior to operating the Phase Sensitive Converter, the above equipment should be connected as shown in Figure 5.1. After making this interconnection, the validity of this test setup can only be checked by operating and testing a Phase Sensitive Converter of known calibration and test limits in order to be sure that minimum ground loops or other sources of error exist.

Use only the first and second decades on the RB-503 Ratio Boxes used for signal input, to assure maximum accuracy.

III. Test Data

DC Offset: With short input, read output
Limit: 0 ±20mv DC in Total and Fund
0 ±10mv DC in Phase Sensistive

MODE	DIRECT	XFMR
IN-PHASE		
QUADRATURE		
TOTAL		
FUND		

AC Noise: Apply 10mv input signal, 10mv range. Observe AC output in mv peak to peak on isolated, calibrated oscilloscope in all modes.

MODE	P/PMV	ACCEPTED LIMIT
Fund/Direct		50mv
Total/Direct		50mv
In-Phase/Direct		50mv
Quad./Direct		50mv

Quadrature Rejection Gradient with Frequency: Apply 10mv signal, 90 degrees leading reference and note output in In-Phase Mode. Should read 0 ±10mv at 400Hz and 0 ±20mv at 380 and 420Hz.

	380Hz		400Hz		420Hz	
MODE	DIR	XFMR	DIR	XFMR	DIR	XFMR
IN-PHASE						
LIMIT	+20mv		+10mv		+20mv	

Amplitude and In-Phase Rejection Gradient with Frequency -

Apply In-Phase Voltage, 10mv at frequencies indicated and note output in Direct and Transformer Modes. Outputs should be 10V ±10mv in Fundamental and In-Phase Modes at 400, 380, and 420Hz. Quadrature Mode outputs should be 0 ±10mv at 400Hz and 0 ±20mv at 380 and 420Hz.

	380 Hz		400 Hz		420 Hz	
	DIR	XFMR	DIR	XFMR	DIR	XFMR
FUND						
IN-PHASE						
SPEC	10V ±10mv	10V ±10mv	10V ±10mv	10V ±10mv	10V ±10mv	10V ±10mv
QUAD.						
SPEC	0 ±20mv	0 ±20mv	0 ±10mv	0 ±10mv	0 ±20mv	0 ±20mv

Reference Error:

Amplitude: Direct Input Signal, In-Phase Mode calibrated with 40V reference. Apply a 100mv In-Phase signal to produce a 10.000 DC output. Change reference voltage to 9V and 127V.

Reference Voltage	In-Phase Signal In-Phase Mode		
		Spec	DATA
40V (±2V)	+10.000		
9V $(^{+2V}_{-0V})$		±2mv	
127V $(^{+0V}_{-2V})$		±2mv	

Quadrature: Direct Input Signal, Quadrature Mode, calibrated with 40V reference, apply a 100mv ±10mv, in-phase signal to produce 0.000V (±1mv) DC output. Change reference voltage to 9V, 20V, and 127V.

Reference Voltage	In-Phase Signal Quad Mode	
	Spec	Data
40V (±2V)	±1mv	
9V $(^{+2V}_{-0V})$	±20mv	
20V (±2V)	±5mv	
127V $(^{+0V}_{-2V})$	±5mv	

Range Check: Apply In-Phase, full scale inputs ±.01% 400Hz

Range Limits: 10V ±10mv except 3V ±10mv for 300V input

Quad. Limits: 0 ±10mv

MODE	Input Range	10mv 10mv	100mv 100mv	1V 1V	10V 10V	100V 100V	300V 1000V
FUND	DIR						
	XFRM						
TOTAL	DIR						
	XFMR						
IN-PHASE	DIR						
	XFMR						
QUAD	DIR						
	XFMR						

Common Mode Test: With unit in Transformer Mode, short input at test panel and apply a 100V, 400Hz common mode voltage between the input and Pin D of J6. Read output and note:

RANGE	10mv		100mv	
		Limit		Limit
IN-PHASE		1V		100mv
QUAD.		10V		1V

Repeat A with 1KΩ resistor at connector, replacing short at Test Panel, and apply 100V, 400Hz to Pin B of J6

RANGE	10mv		100mv		1V	
		Limit		Limit		Limit
IN-PHASE		3V		300mv		30mv
QUAD.				3V		300mv

Maximum limits are noted for each reading

Turnover: With unit in Direct, In-Phase Modes, 10mv Range, 400Hz apply a 10mv Input at a Phase Angle of 0° and adjust Converter to exactly 10.000V using Ratio Box, invert input and record.

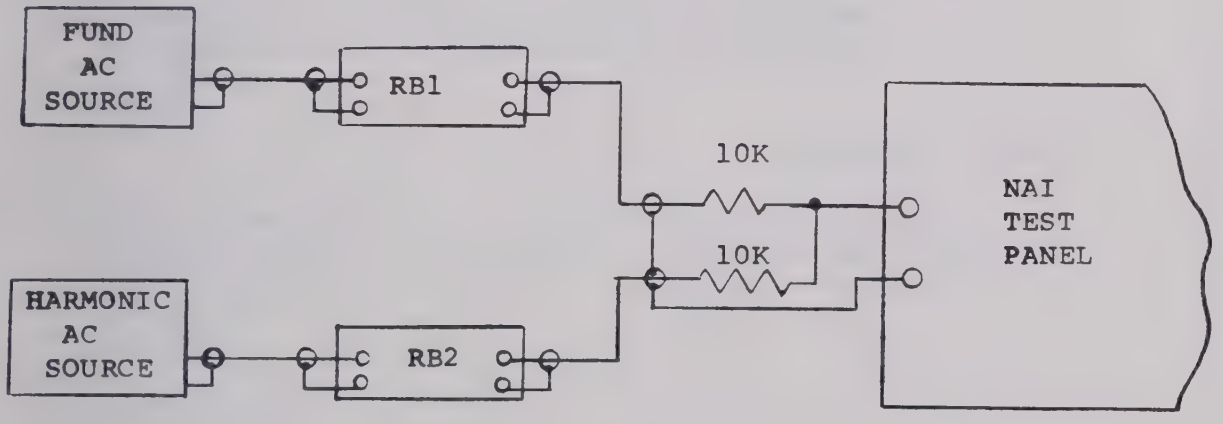
Limit = 10V ±10mv

0°	
180°	

Response Time: Direct Input, In-Phase Mode, 10mv Range.
Switch from 300 volts input to 0 volts input.

TIME OF RECOVERY TO WITHIN ±10mv OF FINAL STEADY STATE VALUE	LIMIT
_____seconds	Less than 1.5 sec.

Harmonic Suppression:



1. Fund, Direct Mode, 1 Volt Range
2. Set RB2 to zero, adjust RB1 for 10V DC Converter output.
3. Record RB1 setting, then turn to zero
4. Monitor the output of RB2 with a VTVM
5. Adjust RB2 for 100mv on the VTVM
6. Remove the VTVM and set RB1 to the value recorded in Step 3.

7. Incrementally vary the frequency of the harmonic AC source for the maximum swing on the output of the Converter. This will normally be when the beat frequency is small.

OUTPUT SWING

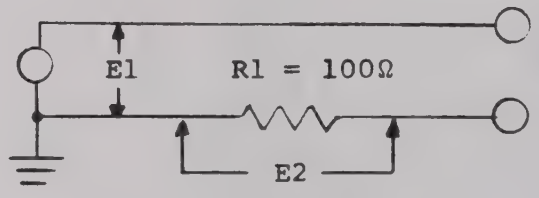
			Limit
2nd harmonic	800Hz	_____MV	16.7mv
3rd harmonic	1200Hz	_____MV	2.8mv

8. The second harmonic output is the total swing of the output. The third harmonic is the total swing of the output divided by two.

NOTE: The reason for making the measurement in this manner is to eliminate the effect of the source impedance of the harmonic AC source and Ratio Box.

Input Impedance

1. Signal - Direct and Transformer. 100V Range - Quad. Mode, apply 100V 400Hz to signal input and compute input impedance at follows:



$$Z_{in} = \frac{E_1 R_1}{E_2}$$

MODE	Z_{IN}	LIMIT
DIR		1 Meg Ohm ±5%
XFMR		400K Ohms Min.

2. **Reference:** Apply 100V, 400Hz to Reference Input and compute impedance as in Step 1.

   Limit = 70K ohms min.

CALIBRATION PROCEDURE

I. The following procedure will identify calibration adjustments which may be required in the event of an out of specification reading during the conductance of the Performance Evaluation Procedure (See Note, Page 5.1). (See Figure 4.4, Calibration Adjustment Locations.)

II. Calibration Adjustments

1. DC Balance - With the instrument programmed to Direct Input, 1000V Range, Quadrature Mode and zero (0) input signal (input terminals shorted), the output should read 0 ± 2mv. If it does not, readjust R1328 to produce an output of as near zero (0) as possible.

2. DC Offset - No adjustment. An out of specification reading indicates a malfunction in the instrument or test set up (check grounds).

3. AC Noise - No adjustment. An out of specification reading indicates a malfunction in the instrument or test set up (check grounds).

4. Quadrature Rejection Gradient with Frequency - Adjust R1116 for 0 ± 10mv at 400Hz.

5. Amplitude and In-Phase Rejection Gradient with Frequency - (Make all adjustments at 400Hz)

   a. For Fund Amplitudes, Direct Input, adjust R1319 for 10V ± 10mv.

   b. For Fund Amplitude, Transformer Input, adjust R1701 for 10V ± 10mv.

   c. For Quadrature Mode, Direct Input (In-Phase Rejection) adjust C1101 for 0 ± 10mv.

   d. For Quadrature Mode, Transformer Input, select new value for C13 to cause 0 ± 10mv.

6. Range Adjustments (Direct Input)

a. 10mv Range:
Fund Mode, adjust R1319 for 10V ± 10mv (repeat of step 5a).

Quad Mode, adjust C1101 for 0 ± 10mv (repeat of step 5b).
Total Mode, adjust R1532 for 10V ± 10mv.

b. 100mv Range:
Fund Mode, adjust R1625 for 10V ± 10mv.
Quad Mode, no adjustment. An out of specification reading indicates a malfunction.

c. 1V Range:
Fund Mode, adjust R1622 for 10V ± 10mv.
Quad Mode, adjust C1612 for 0 ± 10mv.

d. 10V Range:
Fund Mode, adjust R1603 for 10V ± 10mv.
Quad Mode, adjust C1602 for 0 ± 10mv.

e. 100V and 1000V Ranges -These ranges use attenuators adjusted on previous ranges and cannot be independently adjusted.

7. Linearity - No adjustment. An out of specification reading indicates a malfunction.

8. Frequency Response:

a. Direct Input: Select a new value for C11.
b. Transformer Mode: Select a new value for C12.

8. The following are the remainder of the tests performed. These cannot be adjusted and out of specification readings indicate a malfunction.

a. Common Mode
b. Turnover
c. Response Time.
d. Harmonic Suppression
e. Input Impedance

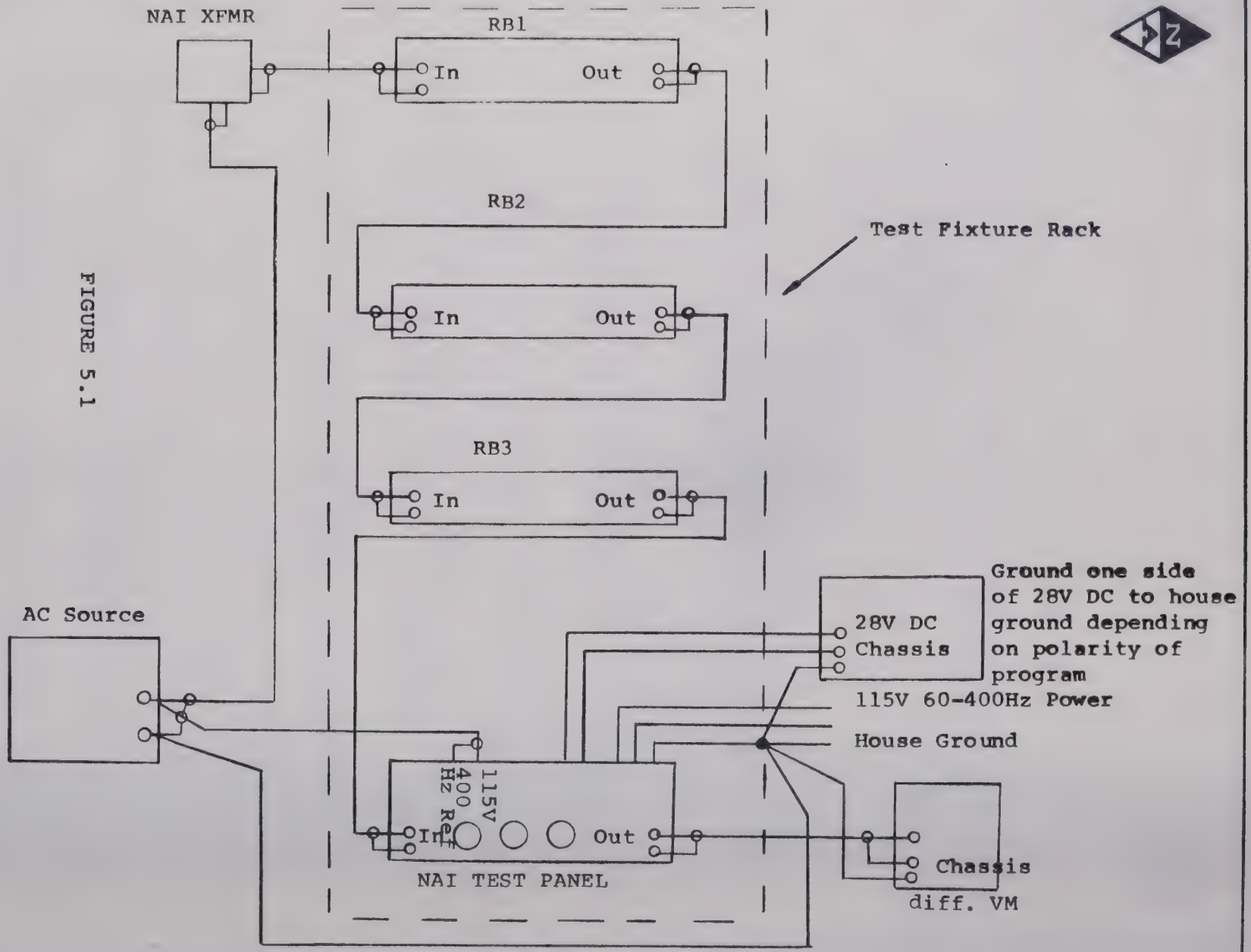

NAI XFMR
RB1
In
Out
RB2
In
Out
RB3
In
Out
Test Fixture Rack
AC Source
28V DC
Chassis
Ground one side of 28V DC to house ground depending on polarity of program
115V 60-400Hz Power
House Ground
115V 400 Hz Ref
In
Out
NAI TEST PANEL
Chassis
diff. VM

FIGURE 5.1

WARRANTY

A. The Seller warrants Products against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of Products which prove to be defective during the Warranty period. There is no charge under the Warranty except for transportation charges. The Purchaser shall be responsible for Products shipped until received by the Seller.

B. The Seller specifically excludes from the Warranty 1) calibration, 2) fuses, and 3) normal mechanical wear, e.g.; end-of-life on assemblies such as switches, relays, gear trains, etc. is dependent upon number of operations or hours of use, and end-of-life may occur within the Warranty period.

C. The Seller is not liable for consequential damages or for any injury or damage to persons or property resulting from the operation or application of Products.

D. The Warranty is voided if there is evidence that Products have been operated beyond their design range, improperly installed, improperly maintained or physically mistreated.

E. The Seller reserves the right to make changes and improvements to Products without any liability for incorporating such changes or improvements in any Products previously sold, or for any notification to the Purchaser prior to shipment. In the event the Purchaser should require subsequently manufactured lots to be identical to those covered by this Quotation, the Seller will, upon written request, provide a quotation upon a change control program.

F. No other Warranty expressed or implied is offered by the Seller other than the foregoing.

CLAIMS FOR DAMAGE IN SHIPMENT

The purchaser should inspect and functionally test the Product(s) in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or if insured separately, with the purchaser's insurance company.

SHIPPING

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in a sealed plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

WARRANTY REGISTRATION

Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required. (Mailed on_____ by_____)

WARRANTY REGISTRATION

Date _____

Please register _____

Model No. _____ Serial No. _____

under the terms of the warranty stated in this Instruction Manual.

Name _____

Title _____ Dept. _____

Company _____

Address _____

City _____ State _____ ZIP _____

Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):

Name _____

Title _____ Dept. _____

For our information please indicate:

Condition of instrument on receipt _____

Application _____

Will the instrument be: resold as part of a system? _____

maintained as company equipment? _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____

Model No. _____ Serial No. _____

We require the following service information: _____

_____

_____

_____

_____

Name _____ Title _____

Company _____ Dept. _____

Address _____

City _____ State _____ ZIP _____

Phone _____ Ext. _____

SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

SERVICE INFORMATION REQUEST

Instrument _____

Model No. _____ Serial No. _____

We require the following service information: _____

_____

_____

_____

_____

Name _____ Title _____

Company _____ Dept. _____

Address _____

City _____ State _____ ZIP _____

Phone _____ Ext. _____

(please send additional Service Information Request cards)

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